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**METHOD AND APPARATUS FOR DYNAMICALLY SELECTING  
FUNCTIONALLY EQUIVALENT WEB SERVICES THROUGH A SINGLE  
AUTONOMIC PROXY**

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**BACKGROUND OF THE INVENTION**

**1. Technical Field:**

The present invention relates to an improved  
10 computing system. More particularly, the present  
invention relates to a method and apparatus for  
dynamically selecting functionally equivalent web  
services through a single autonomic proxy.

**15 2. Description of Related Art:**

A Web service is a business application that may be  
published to a network as a service for remote access and  
invocation by client-side programs. Web services may be  
invoked via defined interfaces that are described in  
20 forms that are discoverable by other software components  
over the network. Industry groups work together to  
define a set of standard Web service interfaces. These  
Web service interfaces are typically (but not required to  
be) based on XML (extensible markup language)-derived  
25 markup languages for all aspects of data exchange and are  
defined by Web services protocols and languages including  
SOAP (simple object access protocol), UDDI (universal  
description, discovery, and integration), and WSDL (web  
service description language). Each of these protocols  
30 and languages is defined by a standard specification.  
SOAP and WSDL are defined by W3C (World Wide Web

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Consortium) standard documents, while UDDI is defined by a standard promulgated by OASIS (Organization for the Advancement of Structured Information Standards), a non-profit industry consortium devoted to the establishment  
5 of standards for electronic business.

UDDI is a form of distributed database for storing and retrieving information about Web services. UDDI is similar in design to DNS (Domain Name Service), which is the distributed database used to map character-based  
10 domain names (e.g., "www.ibm.com") into numerical network addresses for use in routing packets over the Internet. UDDI might also be analogized to a telephone book. Whereas DNS is like the "white pages" (mapping a name to an address), however, UDDI is a bit more like the "yellow  
15 pages," mapping service attributes into service locations and descriptions.

A UDDI registry contains information about Web services. Since UDDI is a distributed database standard, a registry may span a number of different UDDI servers, and, much like DNS, each server is capable of consulting other servers to locate desired Web services. An entry in a UDDI registry will provide information about a particular Web service, including its location (e.g., a URL or uniform resource locator), information about how  
20 to use the service (e.g., as an XML Schema or as a WSDL document), and other attributes that may be useful in identifying a desired service. A client wishing to locate a Web service to meet particular needs can query the UDDI registry to locate entries for Web services that  
25 meet those needs. A consortium of companies, including  
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IBM, Microsoft, and other major vendors, have established a public UDDI registry that may be used, much like DNS, as a master directory to locate listed Web services.

Typically, a UDDI registry will itself be implemented 5 using Web services, so that SOAP or some other comparable protocol can be used for storing or retrieving UDDI registry information.

UDDI is designed to store information about Web services according to classification schemes. UDDI 10 registries may be available to the general public, or only available to specified companies or industry groups. Public business registries include classification schemes such as the Universal Standard Products and Services Classification scheme (UNSPSC) that allow a service 15 requester to select an appropriate business category to search. Private registries, not available to the general public, may be used to increase business security via controlled accesses to services by selecting acceptable participants. These private registries may be used for 20 integrating supply chains, building trading communities, and collaborating with business partners. UDDI does not require the use of any particular classification scheme, and a UDDI entry may include any number of classifications for the purpose of assisting searches. 25 Thus, UDDI provides a convenient way of organizing and indexing information by category or type.

The Web service-related information stored by UDDI 30 registries need not be encoded in any particular language. WSDL, an XML-derived markup language, is specifically designed for encoding descriptive

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information about Web services. WSDL may be used to describe the abstract interface and protocol bindings of arbitrary network services.

Web service interfaces may be defined using the 5 industry standard WSDL and published to the global UDDI registry. As a result, when vendors and other interested parties want to interact with members of these industry groups, the vendors register an implementation of the published interface in UDDI registry. After registering 10 with UDDI, industry group members searching for implementers of the interface may dynamically discover these new vendors. Since multiple vendors have published services that conform to the same interface (as defined by WSDL), the services are said to be functionally 15 equivalent.

Conventional Web service environments may employ proxies to evaluate client requests for a Web service, relay the requests from the client to the Web server, and relay the Web server's answers back to the client.

20 However, typical proxy implementations utilize only one of the potential service implementations returned from a Web service search.

Thus, it would be advantageous to have a method and system for dynamically tuning the Web services 25 environment by providing an autonomic proxy that is able to message multiple functionally equivalent Web services on behalf of the client. Furthermore, it would be advantageous to provide a mechanism for utilizing pluggable algorithms to determine the order of Web 30 service substitution.

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**SUMMARY OF THE INVENTION**

The present invention provides a method and system for dynamically selecting functionally equivalent web services through a single autonomic proxy. The present invention addresses quality of service issues common in the Web service environment, such as failover, redundancy, performance, and security. The present invention may also apply policies based upon non-technical attributes of a service, e.g. business criteria. Such business criteria may be a preferred vendor or business partner or the cost of the service.

The mechanism of the present invention dynamically tunes the Web service environment by allowing an autonomic proxy to determine which Web service, from multiple equivalent Web services, to invoke. A proxy is first configured based on a specific interface found by a wsdlSpec tModel. The policies, which may be specified at the time of deployment, are then matched with policies explicitly expressed by the Web service. When a client request is received, the proxy examines the metadata about the request (e.g., the Web service response time) to determine if the request matches the Web service policy. If the request matches the Web service policy, the autonomic proxy queries the UDDI registry based on the client request. The autonomic proxy then locates multiple Web services candidates to service the client request, wherein each Web service candidate is functionally equivalent to the other Web service candidates.

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**BRIEF DESCRIPTION OF THE DRAWINGS**

The novel features believed characteristic of the invention are set forth in the appended claims. The 5 invention itself, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

10 **Figure 1** is a pictorial representation of a network of data processing system in which the present invention may be implemented;

15 **Figure 2** is a block diagram of a data processing system that may be implemented as a server in accordance with a preferred embodiment of the present invention;

**Figure 3** is a block diagram illustrating a data processing system in which the present invention may be implemented;

20 **Figures 4A and 4B** are block diagrams illustrating components used in dynamically selecting functionally equivalent Web application servers through a single autonomic proxy in accordance with a preferred embodiment of the present invention;

25 **Figure 5** is a diagram of a process by which an autonomic proxy may message multiple functionally equivalent Web services in accordance with a preferred embodiment of the present invention;

30 **Figure 6** is a flowchart of a process by which an autonomic proxy may automatically select the next appropriate service implementer to provide a degree of

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failover to the web service environment in accordance with a preferred embodiment of the present invention; and

5       **Figure 7** is a flowchart of a process by which an autonomic proxy may analyze the Web service response times and dynamically selects the proxy responding the quickest in accordance with a preferred embodiment of the present invention.

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**DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

With reference now to the figures, **Figure 1** depicts a pictorial representation of a network of data processing systems in which the present invention may be implemented. Network data processing system 100 is a network of computers in which the present invention may be implemented. Network data processing system 100 contains a network 102, which is the medium used to provide communications links between various devices and computers connected together within network data processing system 100. Network 102 may include connections, such as wire, wireless communication links, or fiber optic cables.

In the depicted example, server 104 is connected to network 102 along with storage unit 106. In addition, clients 108, 110, and 112 are connected to network 102. Clients 108, 110, and 112 may be, for example, personal computers or network computers. In the depicted example, server 104 provides data, such as boot files, operating system images, and applications to clients 108-112.

Server 104 may be a web application server, such as, for example, IBM WebSphere Application Server, a product of International Business Machines Corporation located in Armonk, New York. Clients 108, 110, and 112 are clients to server 104. Network data processing system 100 may include additional servers, clients, and other devices not shown. In the depicted example, network data processing system 100 is the Internet with network 102 representing a worldwide collection of networks and gateways that use the Transmission Control Protocol/Internet Protocol (TCP/IP)

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suite of protocols to communicate with one another. At the heart of the Internet is a backbone of high-speed data communication lines between major nodes or host computers, consisting of thousands of commercial, government, 5 educational and other computer systems that route data and messages. Of course, network data processing system 100 also may be implemented as a number of different types of networks, such as for example, an intranet, a local area network (LAN), or a wide area network (WAN). **Figure 1** is 10 intended as an example, and not as an architectural limitation for the present invention.

Referring to **Figure 2**, a block diagram of a data processing system that may be implemented as a server, such as server 104 in **Figure 1**, is depicted in accordance 15 with a preferred embodiment of the present invention.

Data processing system 200 may be a symmetric multiprocessor (SMP) system including a plurality of processors 202 and 204 connected to system bus 206. Alternatively, a single processor system may be employed. 20 Also connected to system bus 206 is memory controller/cache 208, which provides an interface to local memory 209. I/O bus bridge 210 is connected to system bus 206 and provides an interface to I/O bus 212. Memory controller/cache 208 and I/O bus bridge 210 may be 25 integrated as depicted.

Peripheral component interconnect (PCI) bus bridge 214 connected to I/O bus 212 provides an interface to PCI local bus 216. A number of modems may be connected to PCI local bus 216. Typical PCI bus implementations will 30 support four PCI expansion slots or add-in connectors.

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Communications links to clients 108-112 in **Figure 1** may be provided through modem 218 and network adapter 220 connected to PCI local bus 216 through add-in boards.

Additional PCI bus bridges 222 and 224 provide 5 interfaces for additional PCI local buses 226 and 228, from which additional modems or network adapters may be supported. In this manner, data processing system 200 allows connections to multiple network computers. A memory-mapped graphics adapter 230 and hard disk 232 may 10 also be connected to I/O bus 212 as depicted, either directly or indirectly.

Those of ordinary skill in the art will appreciate that the hardware depicted in **Figure 2** may vary. For example, other peripheral devices, such as optical disk 15 drives and the like, also may be used in addition to or in place of the hardware depicted. The depicted example is not meant to imply architectural limitations with respect to the present invention.

The data processing system depicted in **Figure 2** may 20 be, for example, an IBM eServer pSeries system, a product of International Business Machines Corporation in Armonk, New York, running the Advanced Interactive Executive (AIX) operating system or LINUX operating system.

With reference now to **Figure 3**, a block diagram 25 illustrating a data processing system is depicted in which the present invention may be implemented. Data processing system 300 is an example of a client computer. Data processing system 300 employs a peripheral component interconnect (PCI) local bus architecture. Although the 30 depicted example employs a PCI bus, other bus

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architectures such as Accelerated Graphics Port (AGP) and Industry Standard Architecture (ISA) may be used. Processor 302 and main memory 304 are connected to PCI local bus 306 through PCI bridge 308. PCI bridge 308 also 5 may include an integrated memory controller and cache memory for processor 302. Additional connections to PCI local bus 306 may be made through direct component interconnection or through add-in boards. In the depicted example, local area network (LAN) adapter 310, Small 10 computer system interface (SCSI) host bus adapter 312, and expansion bus interface 314 are connected to PCI local bus 306 by direct component connection. In contrast, audio adapter 316, graphics adapter 318, and audio/video adapter 319 are connected to PCI local bus 306 by add-in boards 15 inserted into expansion slots. Expansion bus interface 314 provides a connection for a keyboard and mouse adapter 320, modem 322, and additional memory 324. SCSI host bus adapter 312 provides a connection for hard disk drive 326, tape drive 328, and CD-ROM drive 330. Typical PCI local 20 bus implementations will support three or four PCI expansion slots or add-in connectors.

An operating system runs on processor 302 and is used to coordinate and provide control of various components within data processing system 300 in **Figure 3**. The 25 operating system may be a commercially available operating system, such as Windows XP, which is available from Microsoft Corporation. An object oriented programming system such as Java may run in conjunction with the operating system and provide calls to the operating system 30 from Java programs or applications executing on data

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processing system 300. "Java" is a trademark of Sun Microsystems, Inc. Instructions for the operating system, the object-oriented operating system, and applications or programs are located on storage devices, such as hard disk 5 drive 326, and may be loaded into main memory 304 for execution by processor 302.

Those of ordinary skill in the art will appreciate that the hardware in **Figure 3** may vary depending on the implementation. Other internal hardware or peripheral 10 devices, such as flash read-only memory (ROM), equivalent nonvolatile memory, or optical disk drives and the like, may be used in addition to or in place of the hardware depicted in **Figure 3**. Also, the processes of the present invention may be applied to a multiprocessor data 15 processing system.

As another example, data processing system 300 may be a stand-alone system configured to be bootable without relying on some type of network communication interfaces. As a further example, data processing system 300 may be a 20 personal digital assistant (PDA) device, which is configured with ROM and/or flash ROM in order to provide non-volatile memory for storing operating system files and/or user-generated data.

The depicted example in **Figure 3** and above-described 25 examples are not meant to imply architectural limitations. For example, data processing system 300 also may be a notebook computer or hand held computer in addition to taking the form of a PDA. Data processing system 300 also may be a kiosk or a Web appliance.

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The present invention is directed to a method, apparatus, and computer program product for dynamically selecting functionally equivalent Web services through a single autonomic proxy. The present invention addresses 5 quality of service issues common in the Web service environment, such as failover, redundancy, performance, and security. The present invention may also apply the application of business policies, e.g., cost of the service, or preferred provider, in the determination of 10 service invocation. The mechanism of the present invention dynamically tunes the Web service environment by allowing an autonomic proxy to determine which Web service, from multiple equivalent Web services, to invoke.

15 Web services may be invoked via defined interfaces that are described in forms that are discoverable by other software components over the network. Standard Web service interfaces may be defined by industry groups using industry standard WSDL to create WSDL service 20 interface definition documents. These service descriptions, comprising of service interfaces and protocol bindings, and service location, may be queried to locate Web services that conform to the service interface and policy. A policy is a group of assertions 25 that represent the capabilities, requirements, and general characteristics of technical or business entities. An example of an XML-based structure that provides the mechanisms needed to enable Web services applications to specify policy information is WS-Policy 30 (Web Services Policy Framework). Ws-Policy provides a

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model and corresponding grammar to describe the policies of a Web service.

Current methods of discovering policy include locating the information in a public or private UDDI 5 registry or decorating the WSDL with policy information. UDDI is an industry initiative for a universal business registry (catalog) of Web services. UDDI is designed to enable software to automatically discover and integrate with services on the Web. UDDI contains white pages 10 (addresses and contacts), yellow pages (industry classification) and green pages (description of services). The green pages include the XML version, type of encryption and a document type definition (DTD) of the standard. UDDI messages ride on top of the simple object 15 access protocol (SOAP), which invokes services on the Web.

Another mechanism for discovering Web services is WSIL. WSIL is a simple mechanism for Web service discovery that relies on service description mechanisms 20 such as WSDL. WSIL approaches service discovery in a decentralized fashion, where service description information can be distributed to any location using a simple extensible XML document format. Although the invention is described using UDDI in particular, one of 25 ordinary skill in the art will recognize that the teachings of the present invention are not limited to any particular form of discovery mechanism.

Turning next to **Figure 4A**, a block diagram illustrating components used in dynamically selecting 30 functionally equivalent Web application servers through a

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single autonomic proxy is depicted in accordance with a preferred embodiment of the present invention. In this preferred embodiment, each of the components depicted in **Figure 4A** are implemented as Web services using the W3C 5 Web Services Architecture. The various components depicted in **Figure 4A** may be deployed in numerous ways across different data processing systems in an internet, intranet, or local area network.

In this example, autonomic proxy **402** is used to 10 process requests from clients. Autonomic proxy **402** and Web service candidates **404**, **406**, and **408** may be implemented using a data processing system, such as data processing system **200** in **Figure 2**. Clients may be, for example, client **410**. These clients may be implemented, 15 using a data processing system, such as data processing system **300** in **Figure 3**.

When client **410** sends a request to locate a desired Web service, the request is received by autonomic proxy **402**. In response to receiving this request, autonomic 20 proxy **402** may query UDDI registry **412** using standard query patterns described in the UDDI Programmers API (UDDI 12). UDDI registry **412** stores information regarding Web services that may be utilized by clients. Since the UDDI standard supports organizing information 25 according to category, UDDI registry **412** can be searched by category to retrieve entries that provide descriptive information (name, summary description, download location, price, vendor, license terms, etc.) about available software applications in a desired category 30 (e.g., word processors, accounting software, etc.).

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Information retrieved from UDDI registry **412** is used by autonomic proxy **402** to identify candidate Web services for a client request.

**Figure 4B** depicts an example configuration for 5 dynamically selecting functionally equivalent Web application servers through a single autonomic proxy in accordance with a preferred embodiment of the present invention. This configuration illustrates that the present invention as described in **Figure 4A** may be 10 deployed in numerous ways across different data processing systems in an internet, intranet, or local area network. For example, **Figure 4B** shows an application server **430** containing a client **432**, an autonomic proxy **434**, and Web services **436** and **438**. In 15 addition, application server **440** contains Web services **442** and **444**. Client **432** may request a Web service through autonomic proxy **434**, wherein the autonomic proxy selects the appropriate Web service candidates from the available Web services **436**, **438**, **442**, and **444**.

20 In addition, UDDI registry **450** may comprise policy information and a service description. UDDI utilizes a construct called tModels, which represent metadata describing how the Web service behaves, what conventions the Web service follows, or with what standards or 25 services the Web service is compliant. For example, when a service interface is published in the UDDI registry using WSDL, the service interface is referred to as wsdlSpec tModel. A wsdlSpec tModel comprises a uniform resource locator (URL) pointer that points to the 30 corresponding WSDL service interface definition document

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containing the technical specifications required to interact with the Web service endpoint.

Using the standard query patterns described in the UDDI Programmers API (UDDI 12), autonomic proxy 434

5 queries UDDI registry 450 to obtain a Web services definition language (WSDL) Web service interface description for the requested service. WSDL is a protocol for a Web service to describe its capabilities.

WSDL describes the protocols and formats used by the

10 service. WSDL service descriptions can be housed in a UDDI directory, such as UDDI registry 450, and the combination is used to promote the use of Web services worldwide. Based on knowledge of the specifications for the desired Web service, autonomic proxy 434 may discover

15 a wsdlSpec tModel that identifies the desired services. Autonomic proxy 434 may then use the metadata in the wsdlSpec tModel to locate Web services that have registered an implementation of this wsdlSpec tModel.

As mentioned previously, the present invention  
20 addresses the issues of failover, redundancy, and performance common in the Web service environment. In this manner, Web services that implement the same wsdlSpec tModel, or functionally equivalent Web services, may be found. **Figure 5** illustrates a diagram of the  
25 process of using the metadata in the wsdlSpec tModel to locate Web services that have registered an implementation of the wsdlSpec tModel in accordance with a preferred embodiment of the present invention.

The process begins with the Web service client  
30 sending a request for a Web service (step 501). In the

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example, the Web service client sends a request to buy widgets. The autonomic proxy receives the Web service client request and determines if the Web service candidate references have already been discovered (step 5 502). If so, these Web service candidates are used to service the Web service client request. If Web service candidate references have not been created for the request, the autonomic proxy queries the registry using standard query patterns to determine the Web service 10 candidates for the client request (step 503). The registry may store information regarding Web services that may be utilized by clients and may be searched by category to retrieve entries that provide descriptive information (name, summary description, download 15 location, price, vendor, license terms, etc.) about available software applications in a desired category (e.g., word processors, accounting software, etc.). As a result of the query, the autonomic proxy then obtains service metadata to locate one or more functionally 20 equivalent Web services for the requested service (step 504). Based on the metadata for the requested service, the autonomic proxy may then create and store internal Web service candidate invocation references for the requested service (step 505). Once the autonomic proxy 25 obtains candidate Web services, the autonomic proxy may create an instance of a candidate service for a first reference (step 506). The autonomic proxy may also create an instance of a candidate service for a second reference (step 507). The autonomic proxy then 30 prioritizes the Web service candidate references (step

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508). For example, the references may be prioritized based on Web service availability or response time or business criteria. Next, the autonomic proxy messages the selected Web service candidate to service the client 5 request (step 509). The autonomic proxy then analyzes the message metrics to ensure if any of the policies established continue to be met (step 510). For example, if a policy for less than 1 second response time is in effect, and the request takes longer than this time, the 10 policy is violated and the next candidate service reference should be used. In addition, the flexibility of the policy mechanism allows complex business rules to be modeled using the policies.

It must be noted that steps 503-508 as described 15 above in **Figure 5** may be implemented independently of the method of request invocation. Proxy configuring steps 503-508 may also occur prior to the request invocation, such as predetermining the proxy configuration by instantiating the proxy every hour, for example.

20 Turning now to **Figure 6**, a flowchart of a process by which an autonomic proxy may automatically select the next appropriate service implementer to provide a degree of failover to the web service environment is depicted in accordance with a preferred embodiment of the present 25 invention. When the autonomic proxy locates one or more Web services that have registered an implementation of the wsdlSpec tModel (step 602), before utilizing this selected Web service to service the client request, autonomic proxy sends a message to the Web service to 30 determine if the selected Web service is available (i.e.,

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the network link to the selected candidate is available) (step 604). If the selected Web service is available, the selected Web service may service the client request (step 606), the process terminating thereafter.

5       Turning back to step 604, if the autonomic proxy determines that the selected Web service is no longer available, the autonomic proxy may discover the policy of each Web service candidate in the group of Web service candidates (step 608), and select another Web service  
10      from the pool of appropriate candidates based on the policy (step 610). The autonomic proxy sends the client request to the newly selected Web service (step 612). The newly selected Web service may then service the client request (step 614), the process terminating thereafter. In this manner, the autonomic proxy may automatically select the next appropriate Web service implementer to provide a degree of failover and redundancy to the Web service environment.

15      Turning next to **Figure 7**, a flowchart of a process by which an autonomic proxy may analyze the Web service response times and dynamically select the proxy responding the quickest is depicted in accordance with a preferred embodiment of the present invention. When the autonomic proxy locates one or more Web services that  
20      have registered an implementation of the wsdlSpec tModel (step 702), before utilizing this selected Web service to service the client request, autonomic proxy may measure the response times of each Web service by sending messages to each of the Web service candidates (step  
25      704). The autonomic proxy may analyze the responses  
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received and discover the policy of each Web service candidate in the group of Web service candidates (step 706). The autonomic proxy may then dynamically select the Web service that is responding the quickest according 5 to the policy (step 708). The selected Web service may then service the client request (step 710), the process terminating thereafter. In this manner, the present invention may dynamically tune the Web service environment and select which Web service to invoke.

10 Thus, the present invention provides a method, apparatus, and computer program product for dynamically selecting functionally equivalent Web services through a single autonomic proxy. The advantages of the present invention should be apparent in view of the detailed 15 description provided above. A proxy may be used to message a Web service returned from a wsdlSpec tModel search. However, conventional proxy implementations utilize only one of the Web services returned from the search. In contrast, the present invention provides a 20 mechanism to address quality of service issues common in the Web service environment, such as failover, redundancy, performance, and security by providing an autonomic proxy to message multiple functionally equivalent Web services. In this manner, the proxy may 25 dynamically determine which Web service to invoke. For example, if the network link to the original service provider is no longer available, the proxy may automatically select the next appropriate service implementer and dispatch the message again. This scheme 30 provides a degree of failover and redundancy to the Web

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service environment. In addition, the autonomic proxy may dynamically tune the Web service environment to select the Web service that responds more quickly than the others. For example, the autonomic proxy may analyze 5 the response times of the equivalent Web services and dynamically select the Web service that responds most quickly.

It is important to note that while the present invention has been described in the context of a fully 10 functioning data processing system, those of ordinary skill in the art will appreciate that the processes of the present invention are capable of being distributed in the form of a computer readable medium of instructions and a variety of forms and that the present invention 15 applies equally regardless of the particular type of signal bearing media actually used to carry out the distribution. Examples of computer readable media include recordable-type media, such as a floppy disk, a hard disk drive, a RAM, CD-ROMs, DVD-ROMs, and 20 transmission-type media, such as digital and analog communications links, wired or wireless communications links using transmission forms, such as, for example, radio frequency and light wave transmissions. The computer readable media may take the form of coded 25 formats that are decoded for actual use in a particular data processing system.

The description of the present invention has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the 30 invention in the form disclosed. Many modifications and

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variations will be apparent to those of ordinary skill in the art. The embodiment was chosen and described in order to best explain the principles of the invention, the practical application, and to enable others of 5 ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.